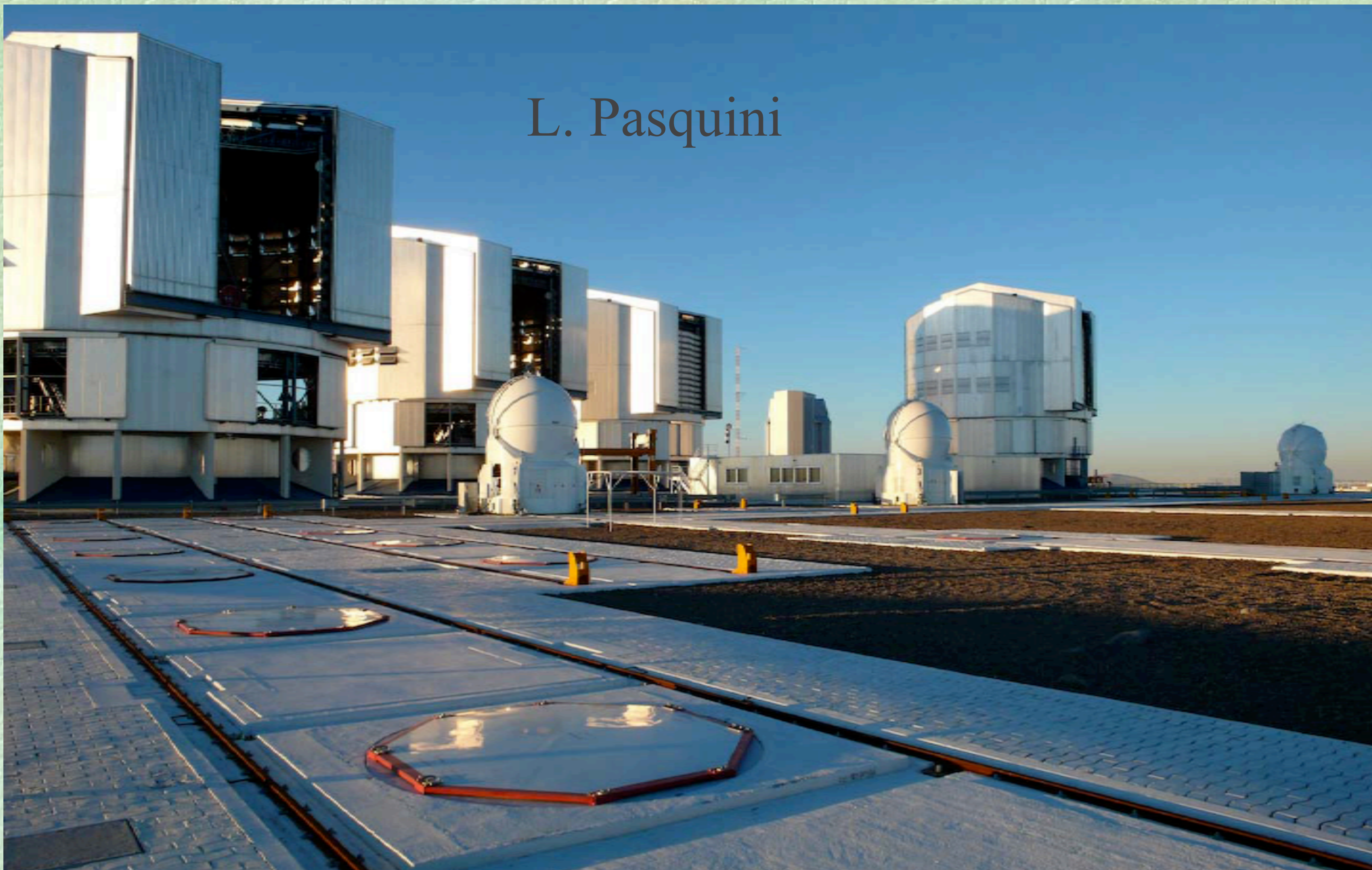
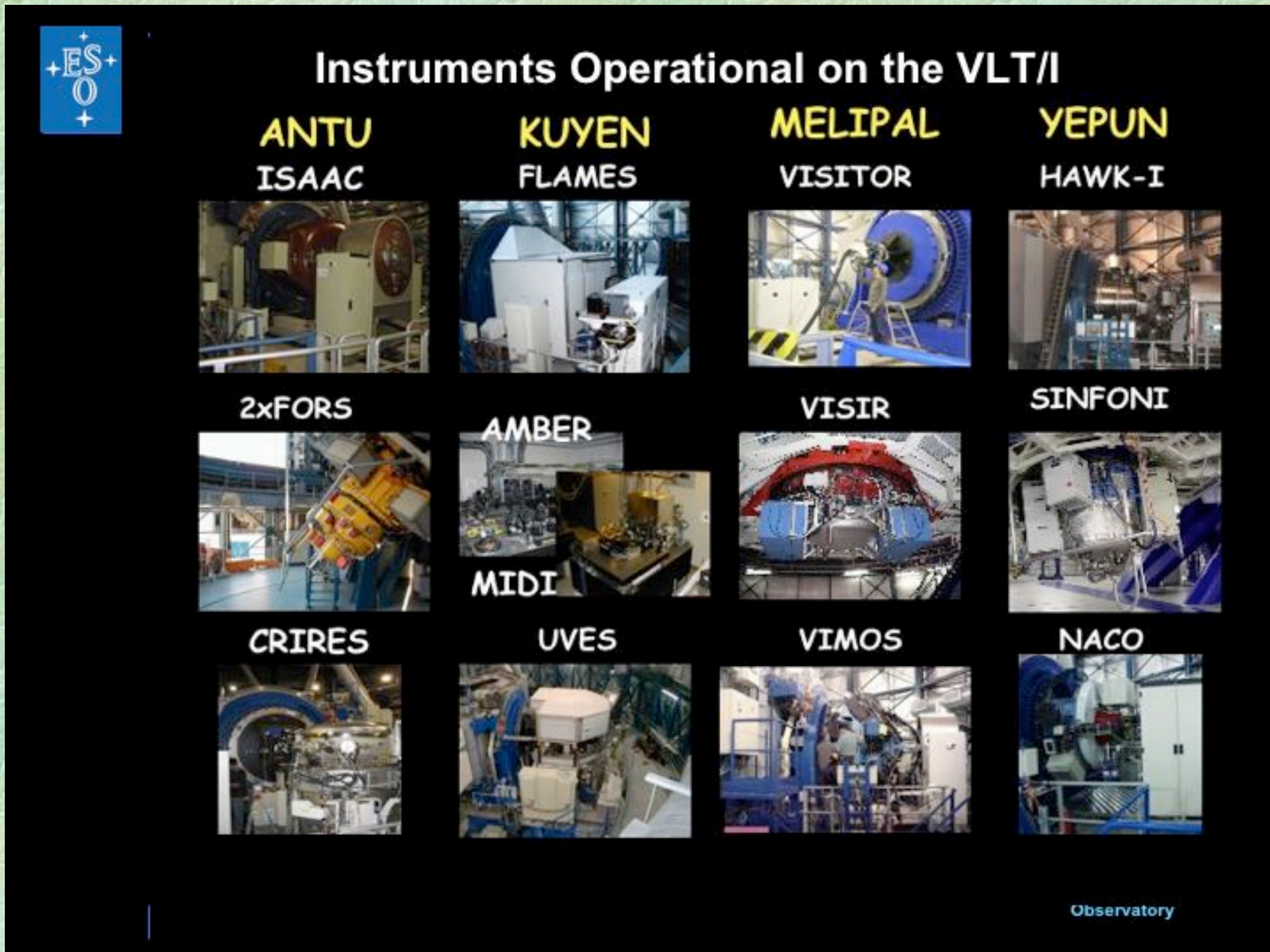
VLT / VLTI Future Instruments



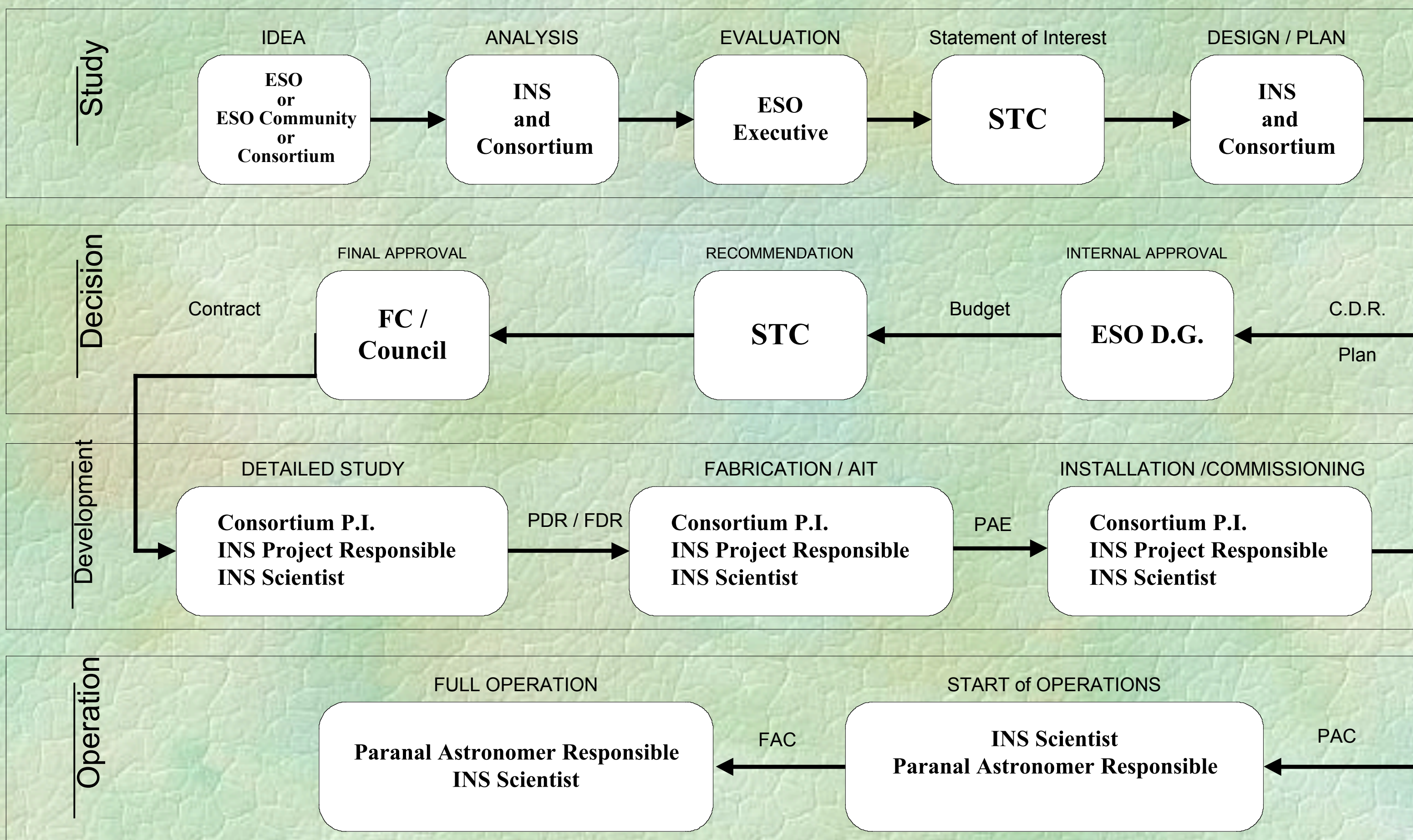
L. Pasquini

VLT 1st Generation Instruments



INSTRUMENTATION DIVISION

VLT INSTRUMENTS DEVELOPMENT TRACK



1st Generation Lesson Learned

Management and Contracts

- Upfront R&D, Phase A added.
- Agreement on use of Management Tools
- More ESO-Consortium Partnership
- Global approach (including operations), close involvement prior to PAE
- Commissioning painful. Early science added. Early involvement Paranal

Technical Aspects

- Instruments have too many modes.
- Positive overall evaluation of VLT (HW and SW) standards
- Move towards pipelines which produce science products.

2ND Generation VLT/I Instruments

X-Shooter OFFERED by OCT09 (Operations)

Fabrication/AIT

KMOS (2011)

MUSE (2012)

SPHERE (2011)

AOF @ UT4 (2013): Enhance MUSE and HAWKI

Detailed Study

VLTI: MATISSE (2014 :) Study (PDR)

VLTI: GRAVITY (2015 :) Study (PDR)

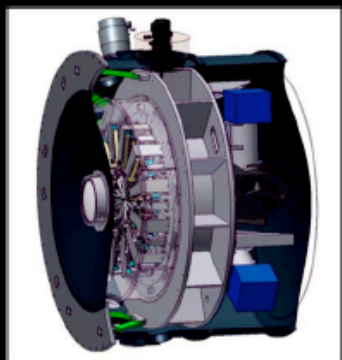
Phase A

ESPRESSO (2015 :)

KMOS

- Investigate the physical processes which drive galaxy formation and evolution over red shift range $1<z<10$.
- Map the variations in star formation histories, spatially resolved star-formation properties, and merger rates
- Dynamical masses of galaxies across a wide range of environments at a series of progressively earlier epochs
- Extremely High-Redshift Galaxies and Re-ionisation
- The Connection Between Galaxy Formation and Active Galactic Nuclei
- Age-Dating of Ellipticals at $z = 2$ to 3

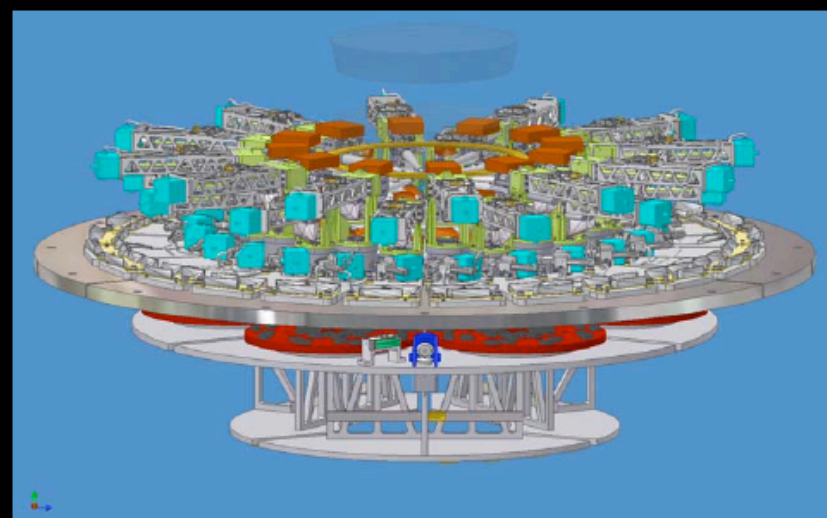
KMOS



FDR in Sept 07 following 6 Subsystem Assembly Reviews

PPARC, Durham, Oxford,
Edinburgh (ATC)
Garching (MPE)
Munich Observatory

- Mass assembly of galaxies
- Galaxies at z>7
- Age dating of galaxies
- Star formation



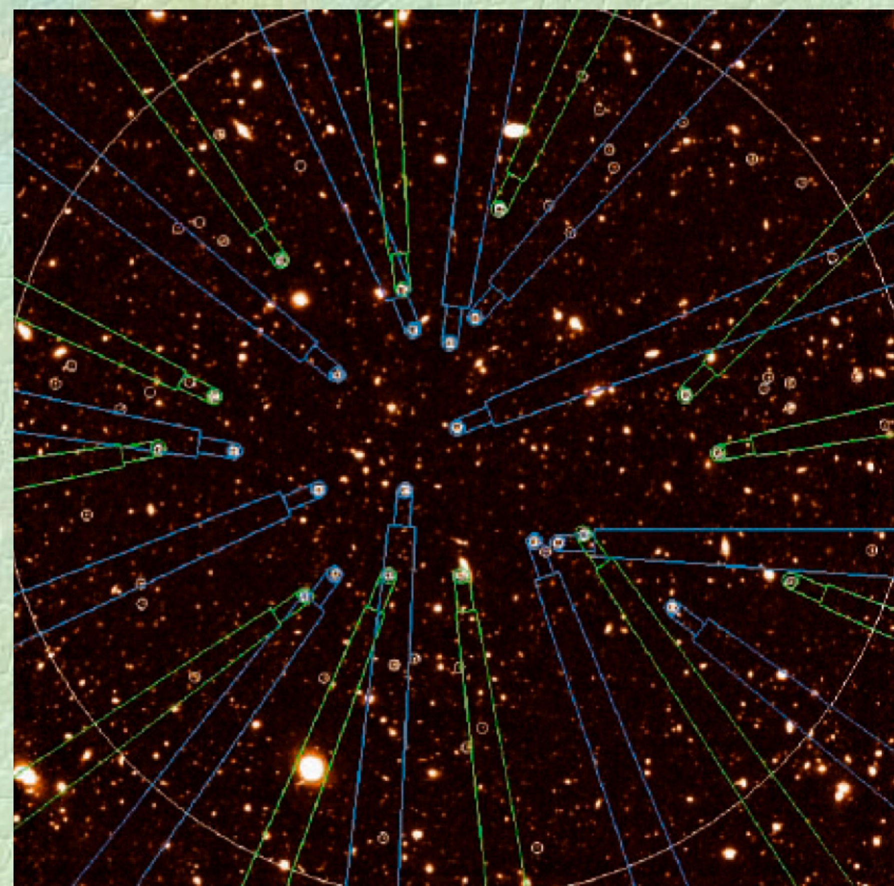
- Fully cryogenic deployable pick-off arms
- 24 IFUs; 0.2" pixels; 7'.2 dia. Field
- Wavelength range: 1-2.45μm
- R~3500; 3(2k x 2k) Detectors

European Southern Observatory

KMOS

UKATC/MPE/USM/U.Durham/U.Oxford

- 24 deployable arms/IFUs
- 7’ diameter pickoff field
- 14x14 spatial elements/IFU
- R = 3400-3800
- 3 x 2kx2k H2RG detectors
- First light 2011



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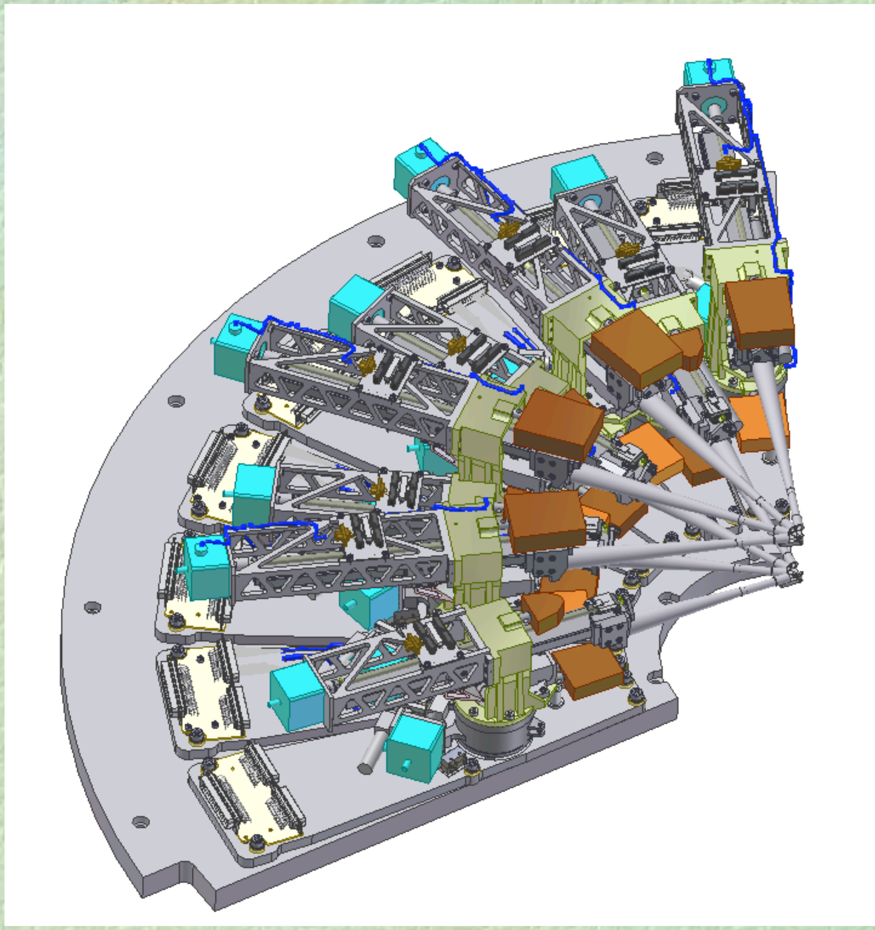


KMOS Under Construction

MUSE: Science

3D Ultra Deep Field: 10^{-19} erg s^{-1} cm^{-2}
Faint Ly α emitters; Progenitors of Milky Way ?
Star Formation History at Z>4
Development of dark matter halos
Link between Ly α emitters and High Res. QSO absorption

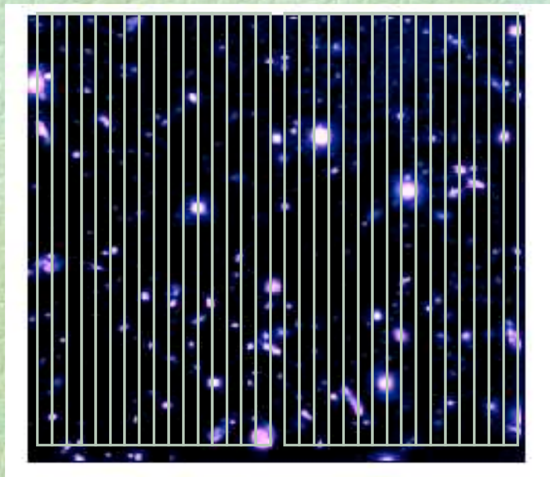
Physics of high Z galaxies from resolved spectroscopy

Kinematics, population, cluster, outflows, merger...
in (nearby) galaxies

Stars: massive spectroscopy of crowded regions,
Origin of bipolar stellar outflows and shock waves

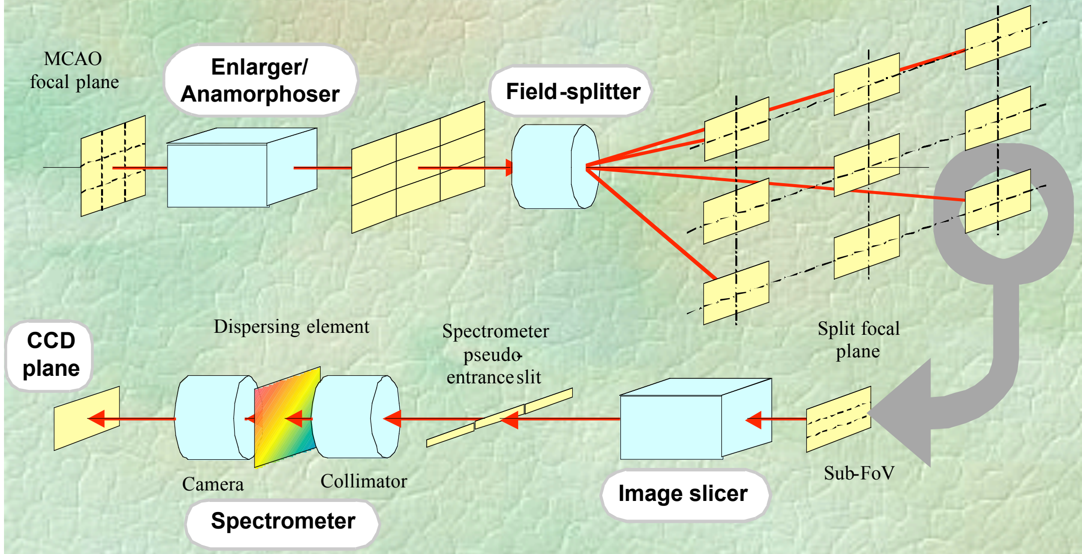
SIMULTANEOUSLY + SERENDIPITY

MUSE



CRAL-Lyon (R. Bacon, PI)

ESO, Touluse, Leiden, ETH, Gottingen, Postdam



1' x 1' field IFU; 0.48-0.95 µm

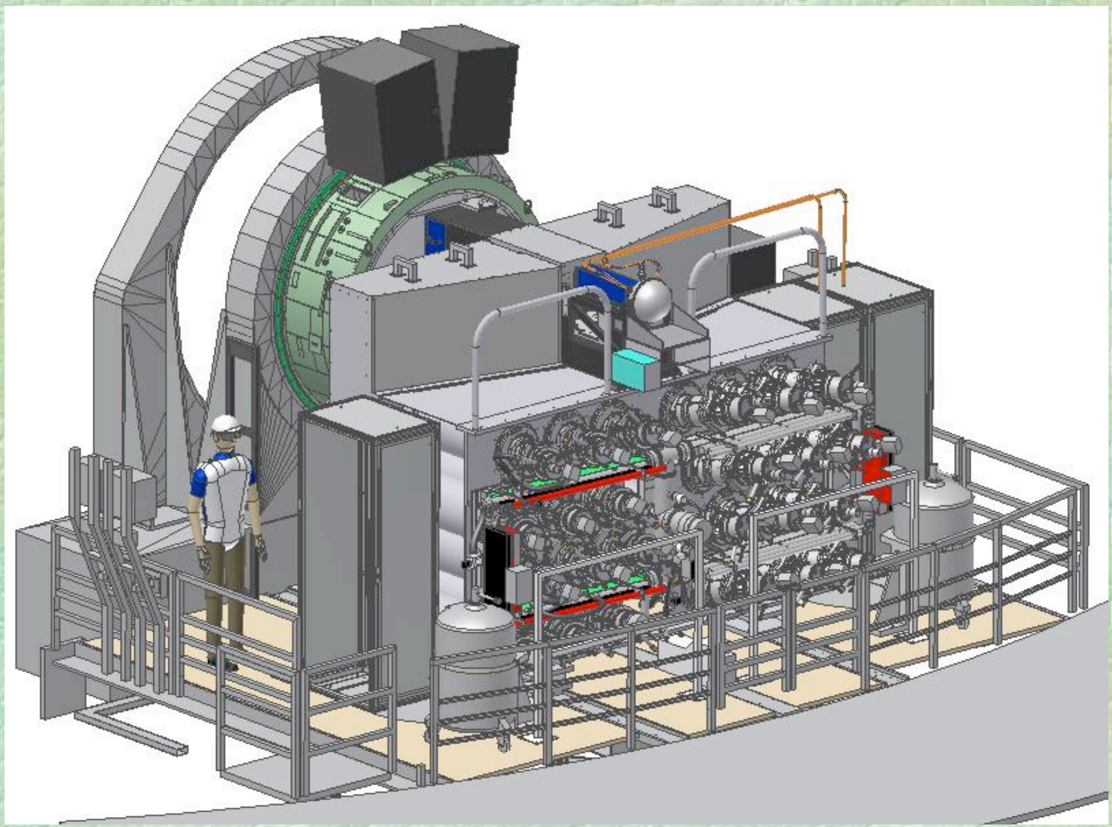
24 Spectrometers (4k x 4k)

No moving part, Nasmyth (fixed)

$\Re \sim 3{,}000$

GLAO

MUSE Design

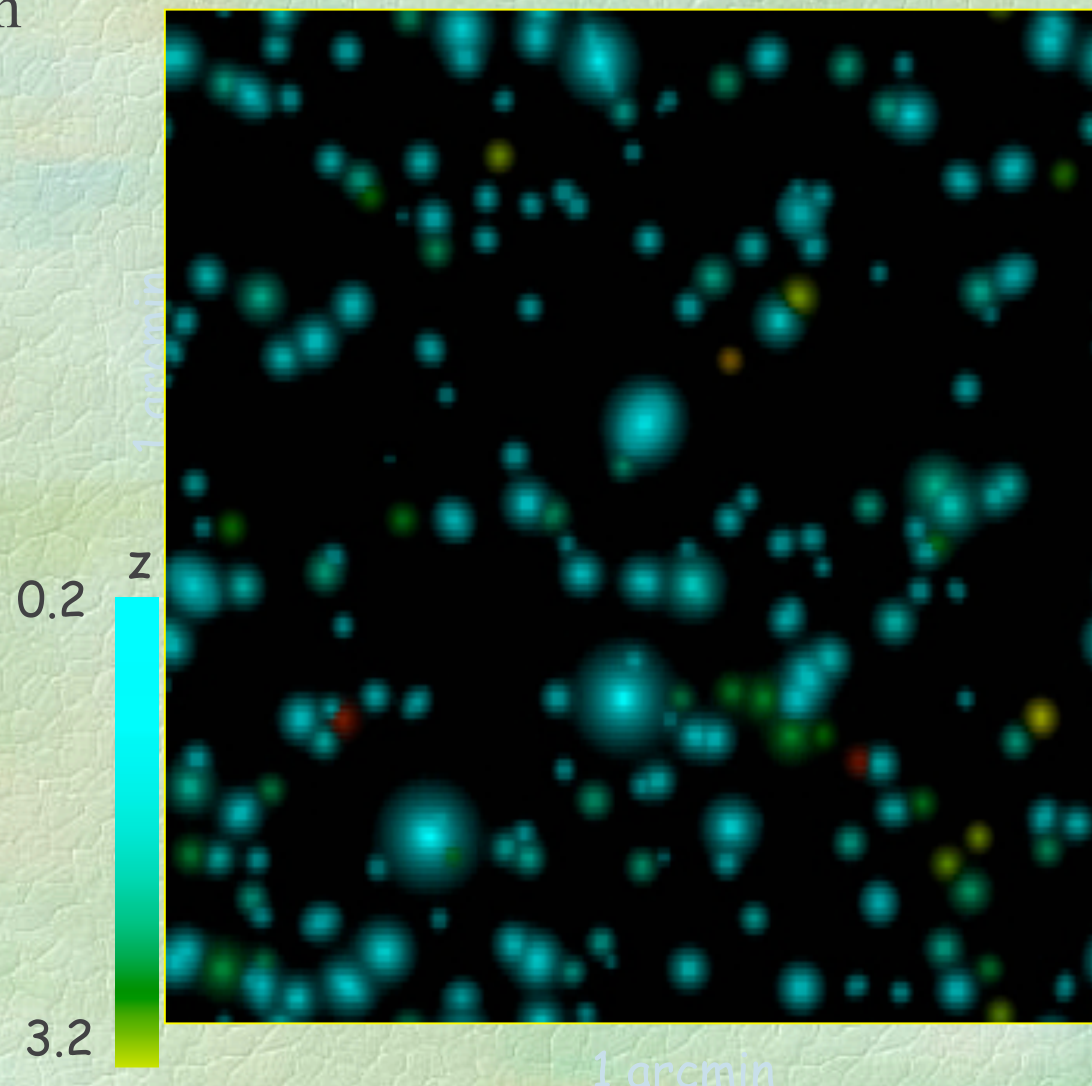


- 1'x1' field. GLAO
- 0.2" sampling
- 0.46-0.93 microns
- R=3000
- 24 spectrographs

- 7.5"x7.5" NF mode
- high strehl (10-30%)

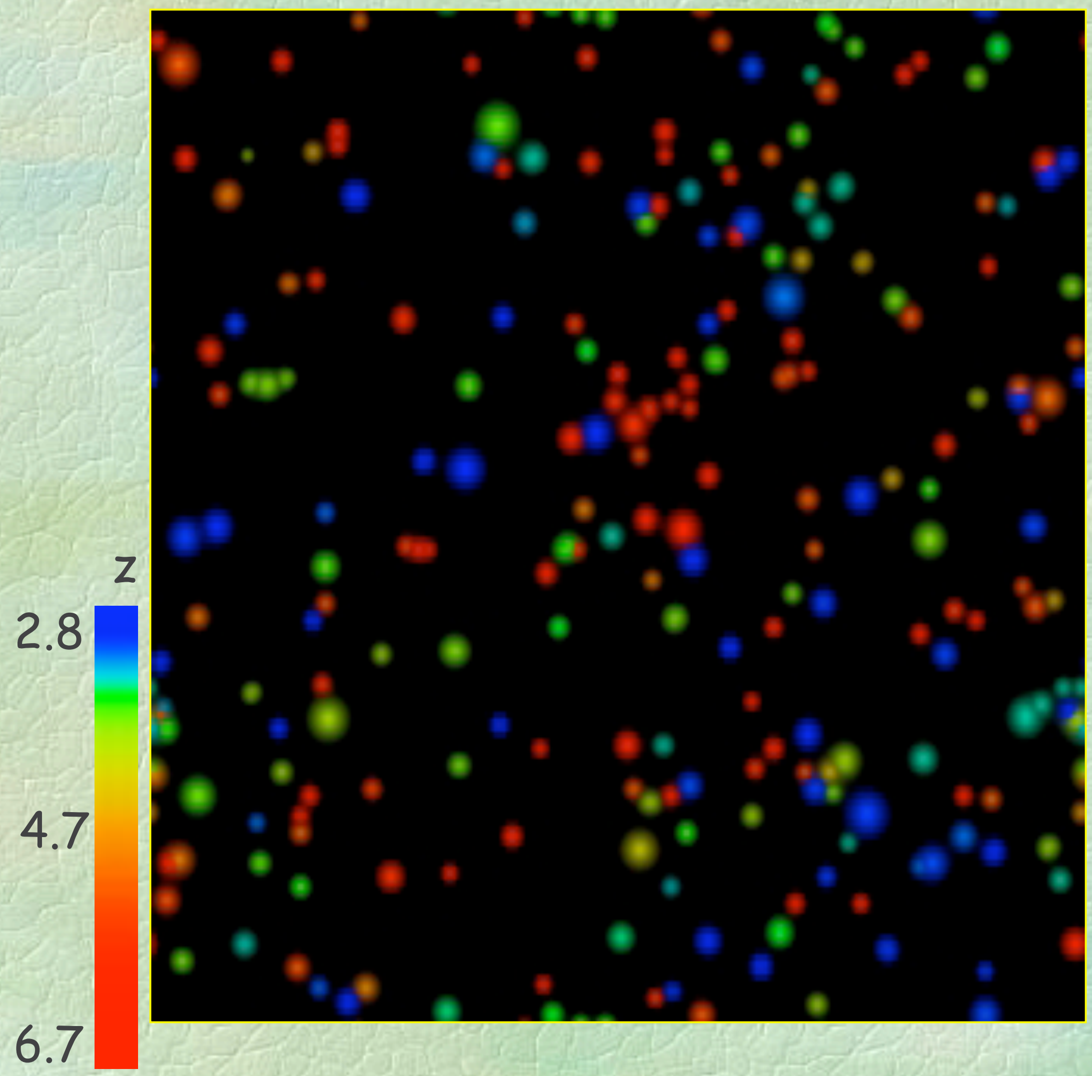
MUSE Deep field

- Continuum detection
  - $I_{AB} < 26.7$
  - Reduced R (300)
  - 154 gal. arcmin^{-2}
  - 95% at z<3



MUSE Deep Field - Lyα

- Lyα detection
  - Flux Lyα > $2.5.10^{-19}$ $erg.s^{-1}.cm^{-2}$
  - 245 gal. $arcmin^{-2}$
  - 113 gal. in z [2.8-4]
  - 132 gal. in z [4-6.7]



MUSE : some HW

SPHERE
Spectro-Polarimetric High-contrast Exoplanet Research

A Planet Finder Instrument for the VLT

Jean-Luc Beuzit (PI) and numerous participants from 12 European institutes !

LAOG, MPIA, LAM, ONERA, LESIA, INAF, Geneva Observatory, LUAN, ASTRON, ETH-Z, UvA, ESO

SPHERE Science

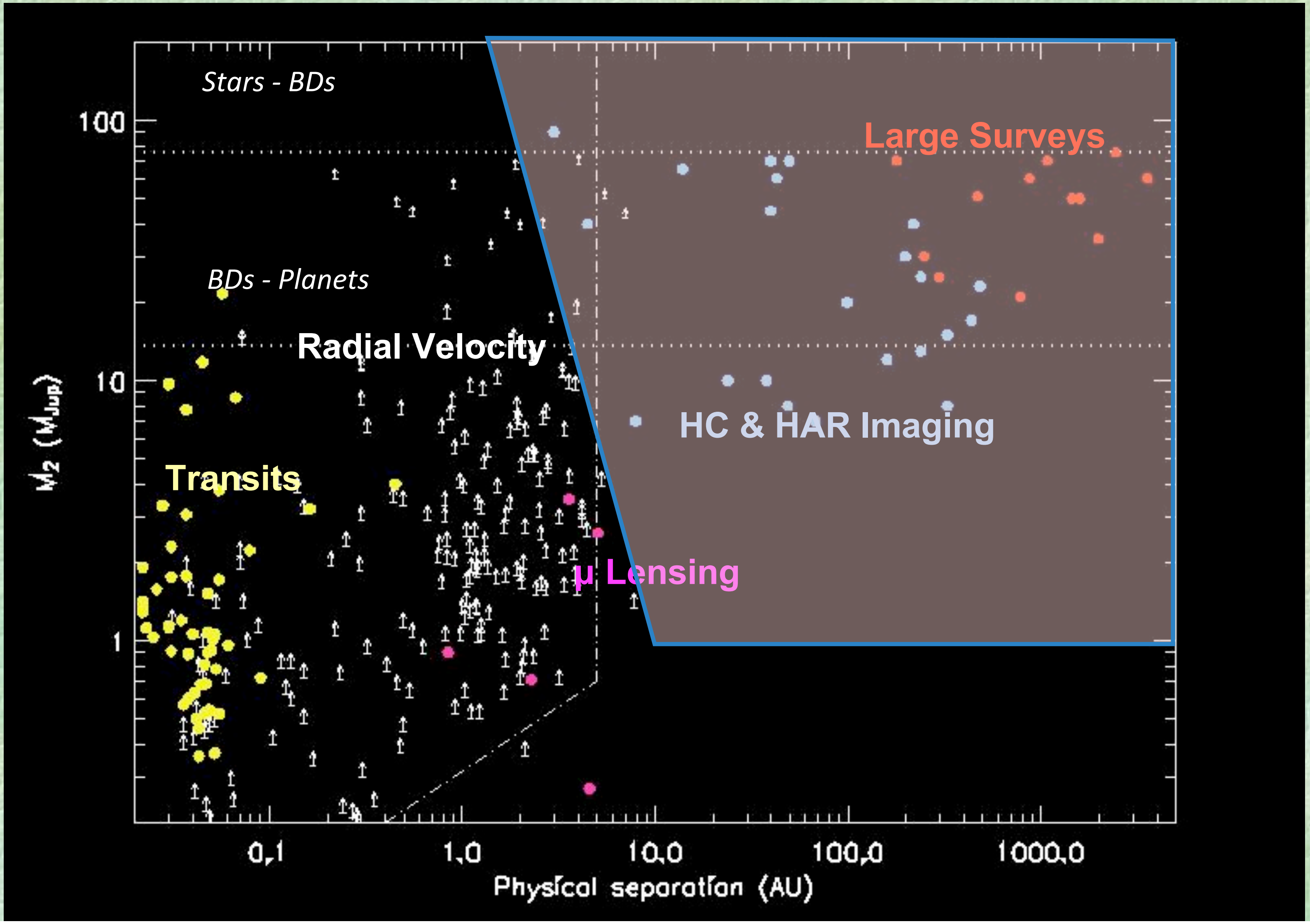
Direct detection of extra-solar planets, large statistics, dependence on mass, variety, fill up the Mass-Period diagram, atmospheres

Evolved planetary systems by reflected light (mostly by visible differential polarimetry)

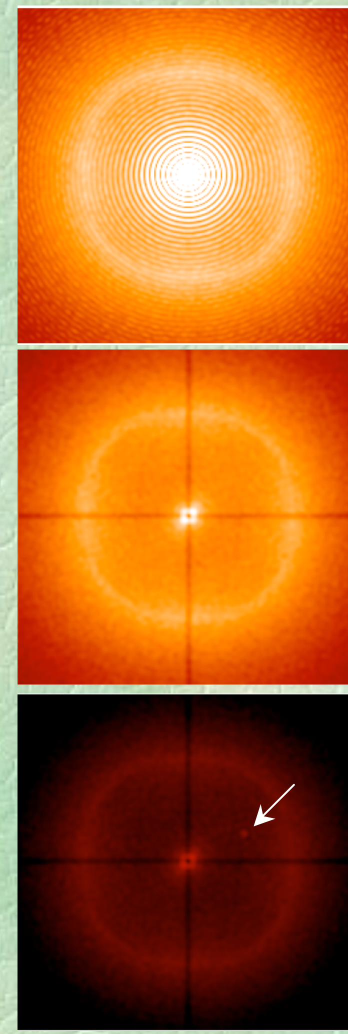
Young planetary systems: intrinsic planet emission (using IR differential imaging and integral field spectroscopy).

Complementary detection capacities and characterization potential, in terms of field of view, contrast, and spectral domain.

Science objectives

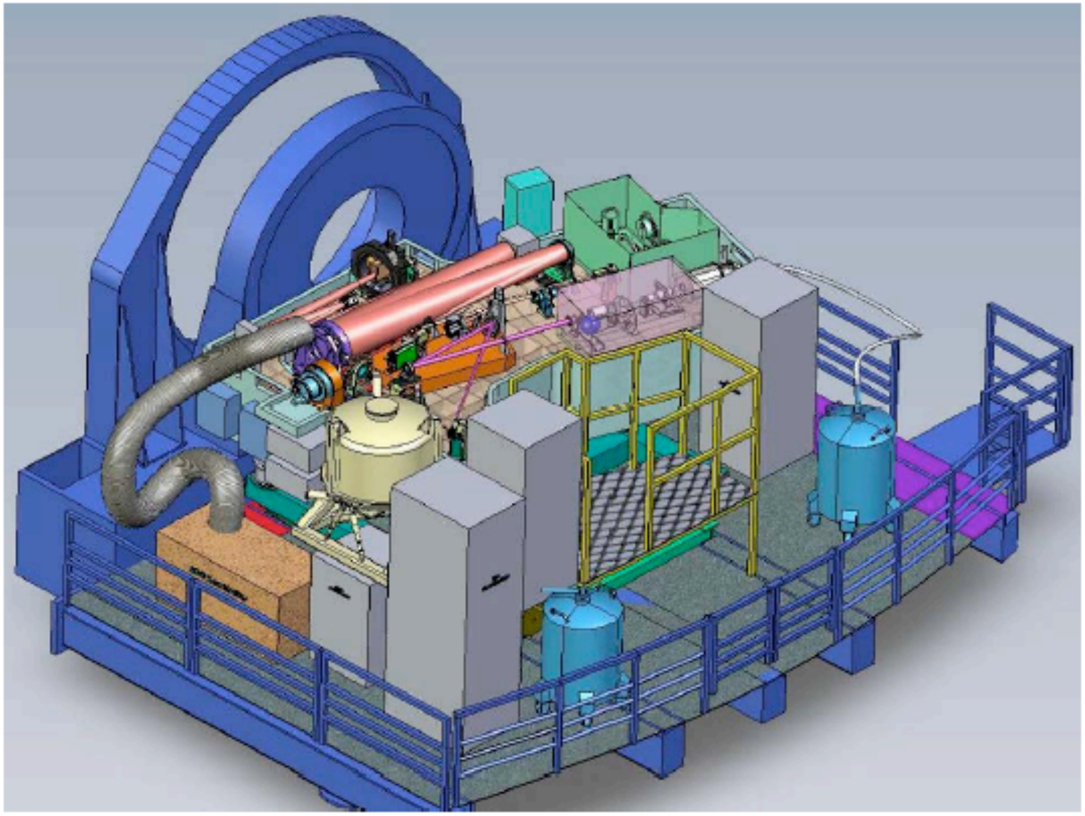


High Level Requirements



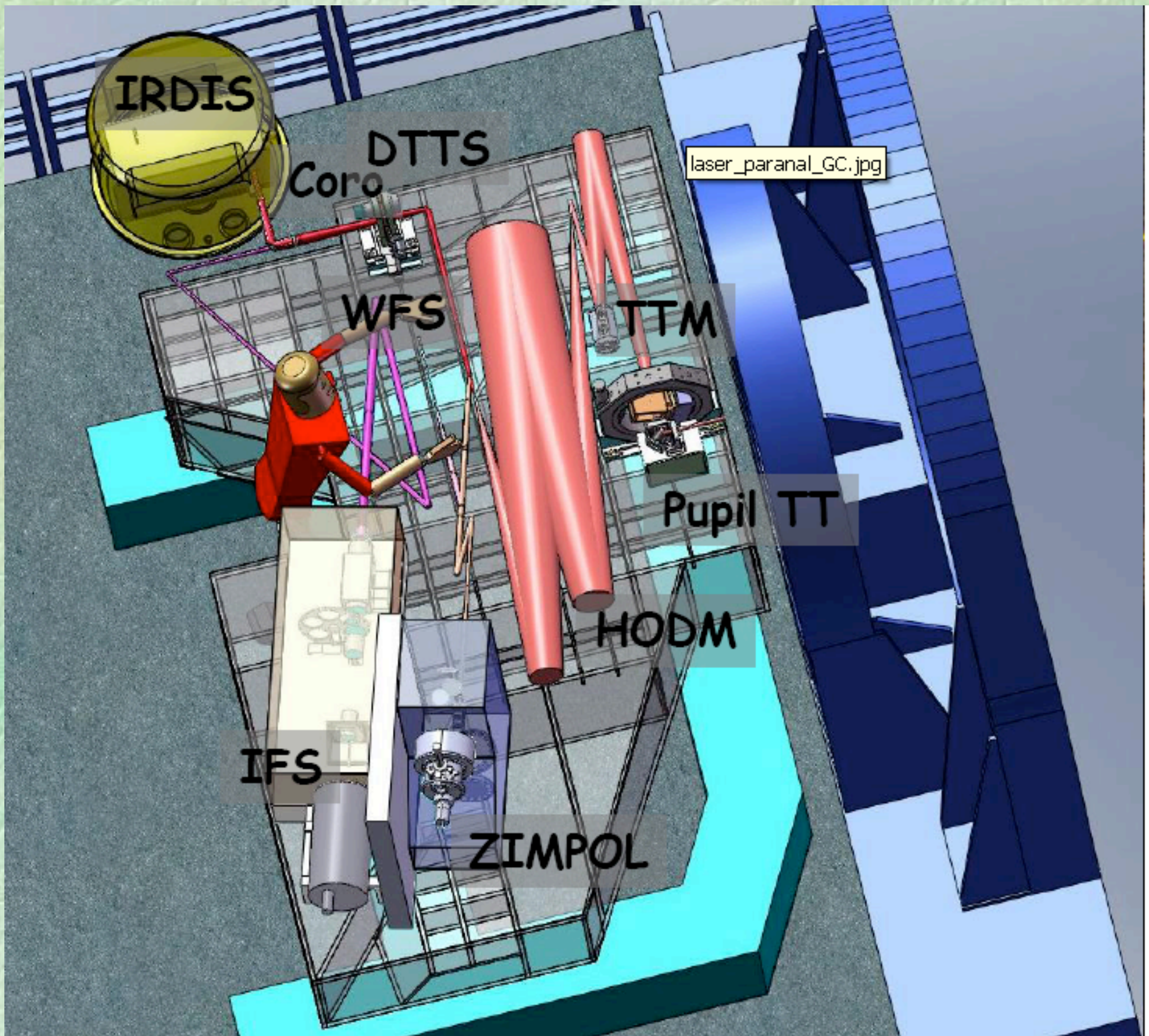
- Scientific requirements
  - ✓ Gain up to 2 orders of magnitude in contrast
  - ✓ Reach short separations: 0.1" – 3" (1- 100AU)
  - ✓ Survey a large number of targets (V<10)
  - ✓ spectral coverage
- High contrast detection capability
  - ✓ Extreme AO (turbulence correction)
    - ✓ feed coronagraph with well corrected WF
    - ✓ SR ~ 90% in H-band
  - ✓ Coronagraphy (removal of diffraction pattern)
    - ✓ high dynamics at short separations
  - ✓ Differential detection (removal of residual defects)
    - ✓ calibration of non common path aberrations
    - ✓ pupil and field stability
    - ✓ smart post processing tools

At the diffraction limit



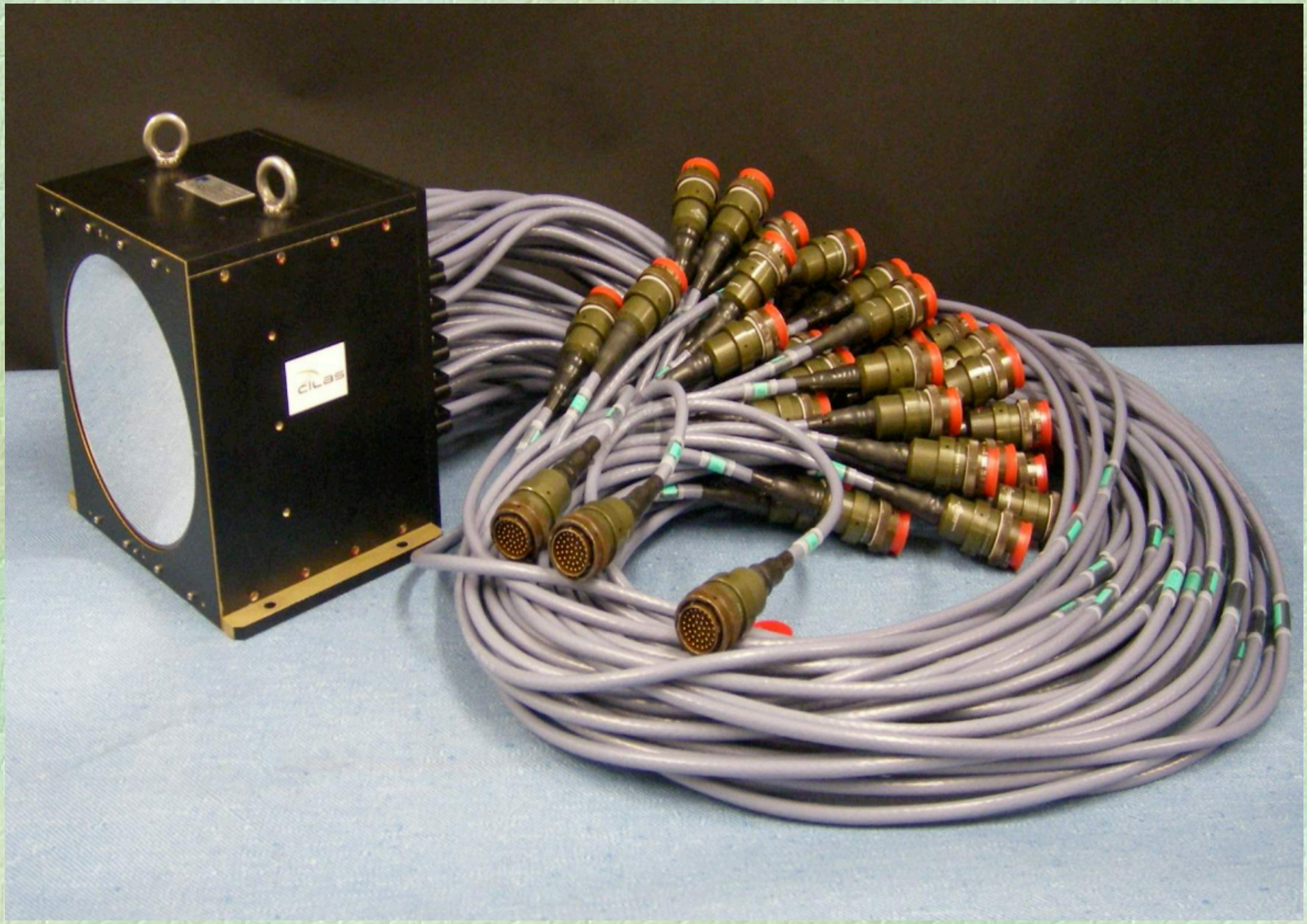
- XAO System
- IRDIS: dual IR camera
- IFS: Near IR integral field spectrograph
- ZIMPOL: visible polarimeter

SPHERE



- Optical bench attached to VLT **Nasmyth platform**
- **Cover** to protect from dust and damp thermal variations
- **XAO** with ~1300 actuators and 1.2 kHz to produce S~90% at H-band (S~50% at 0.7 μm)
- Telescope **pupil stabilized** in rotation and translation

SPHERE: the deformable mirror!



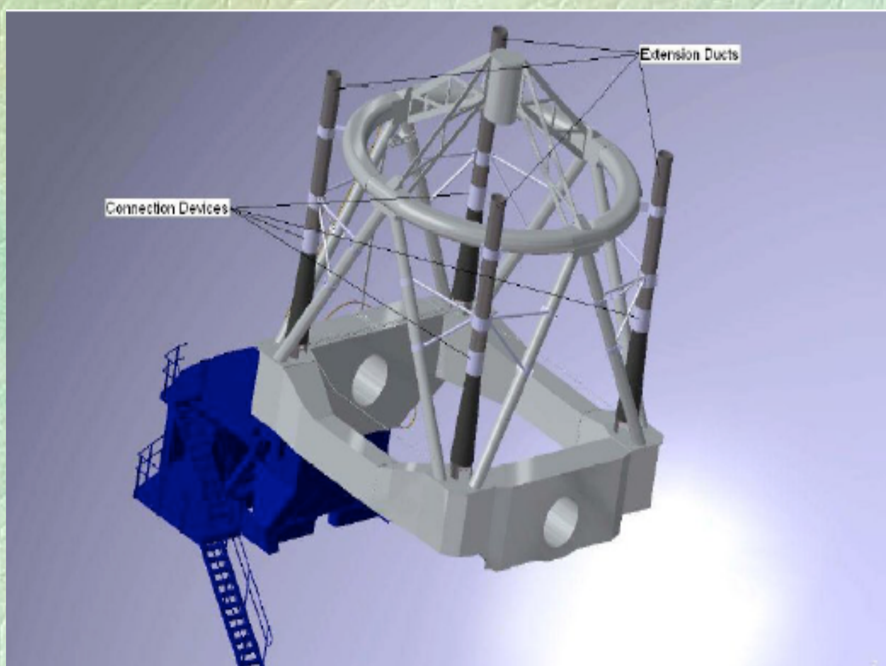
Seeing-improved - GLAO

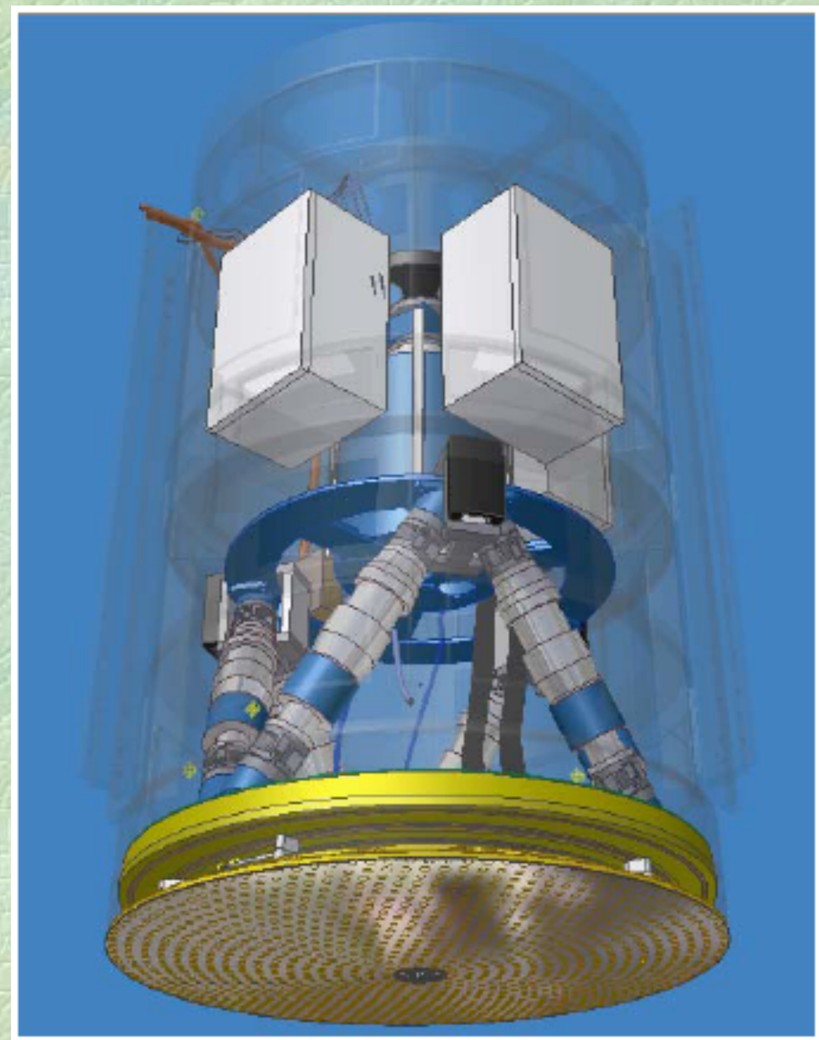
- Adaptive Optics Facility for UT4 (2013)
  - 1.1m deformable M2 with 1170 actuators
  - 4 Na laser guide stars
  - Wavefront sensors for two Nasmyth ports/instruments
  - SPARTA real time computer platform

2mm

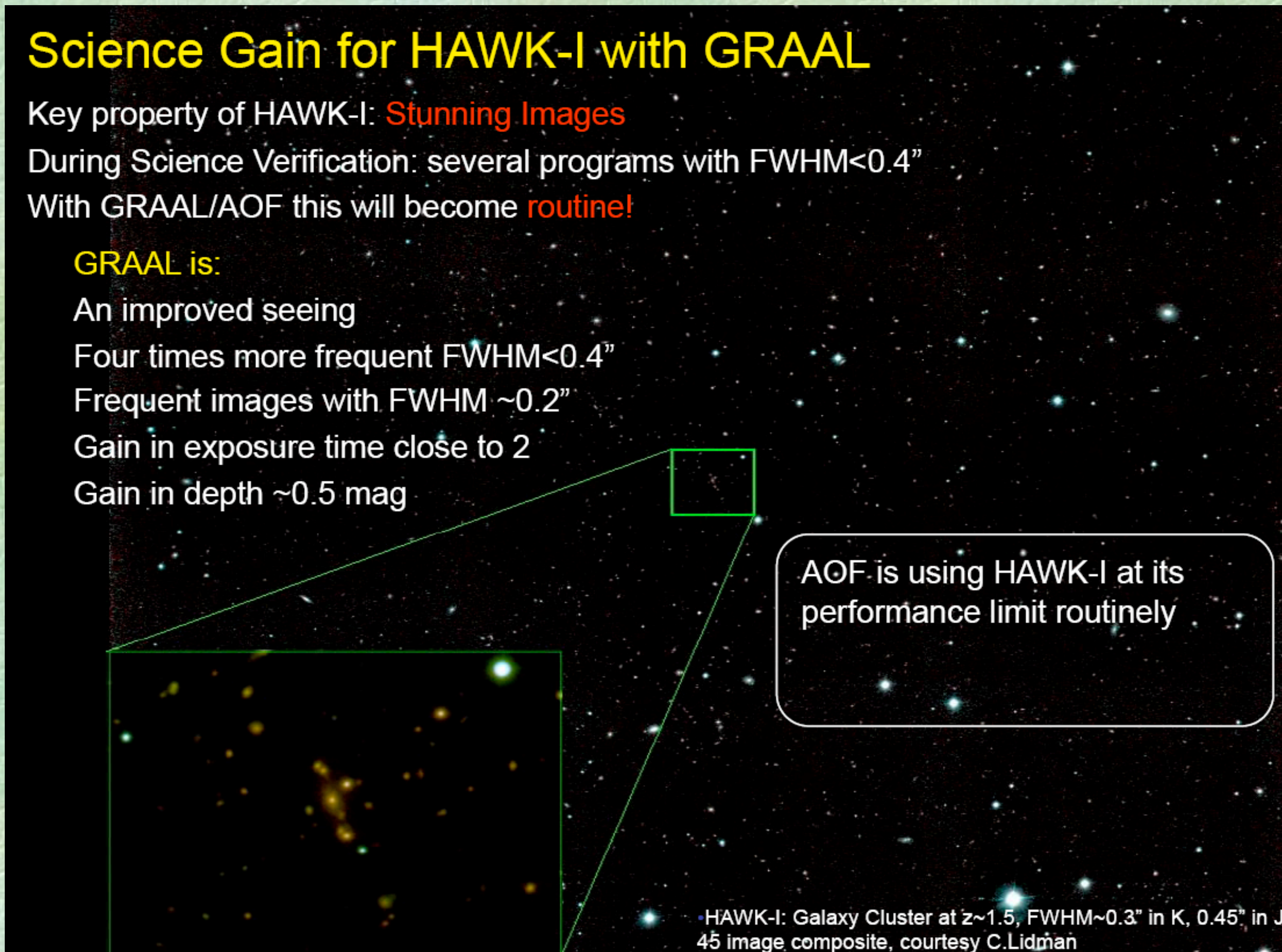
Adaptive Optics Facility

- Conjugated to Ground Layer
- *Seeing improver* over wide field

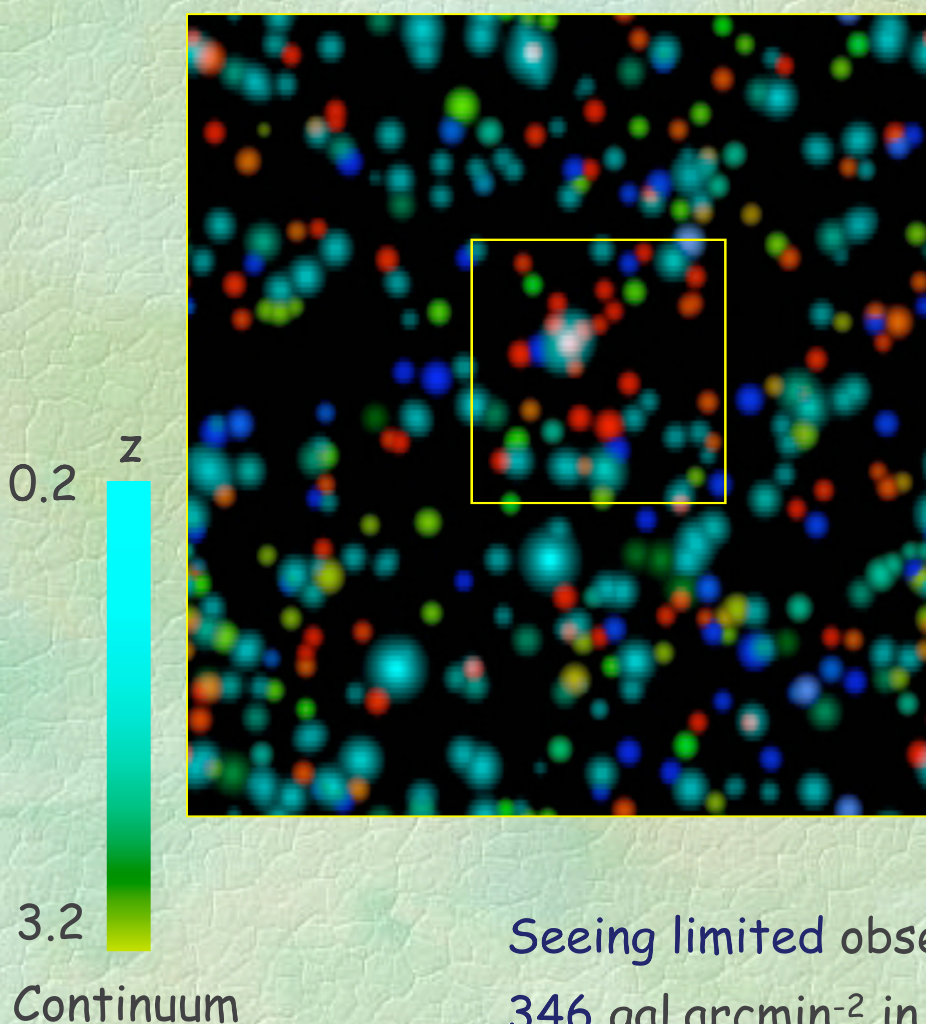


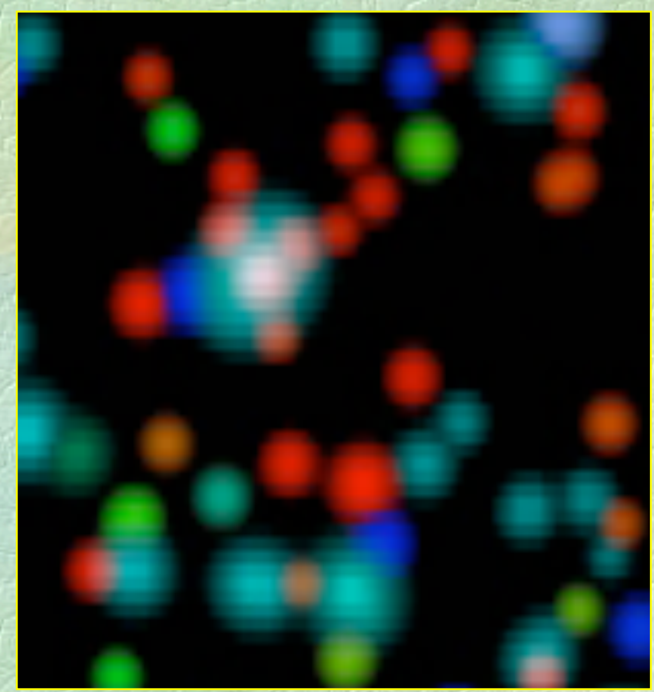


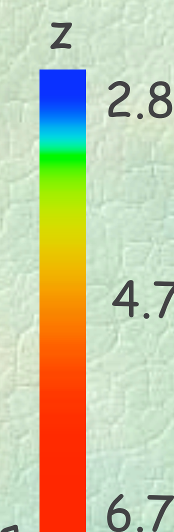
Seeing-improved HAWK-I



Source confusion





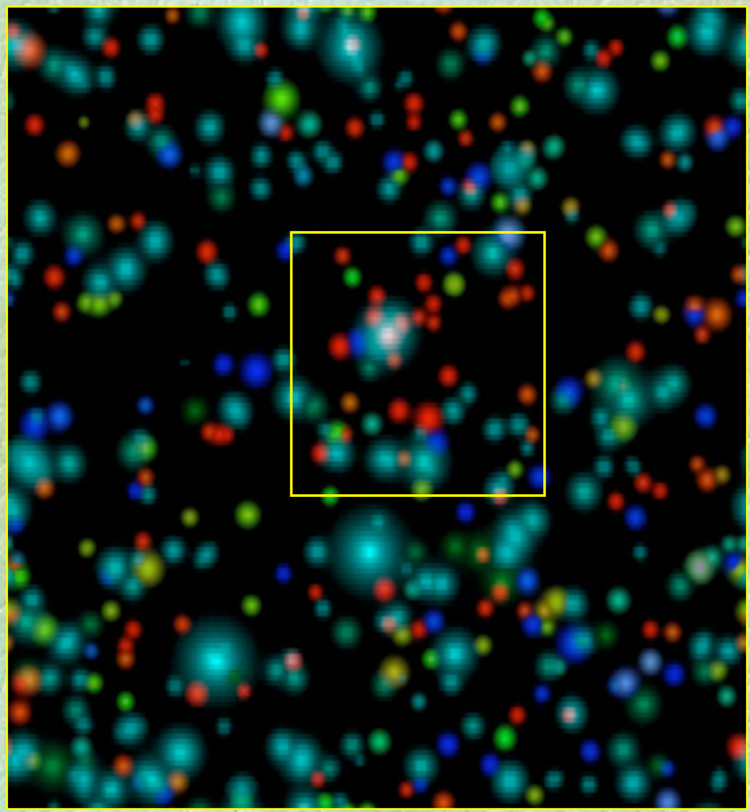


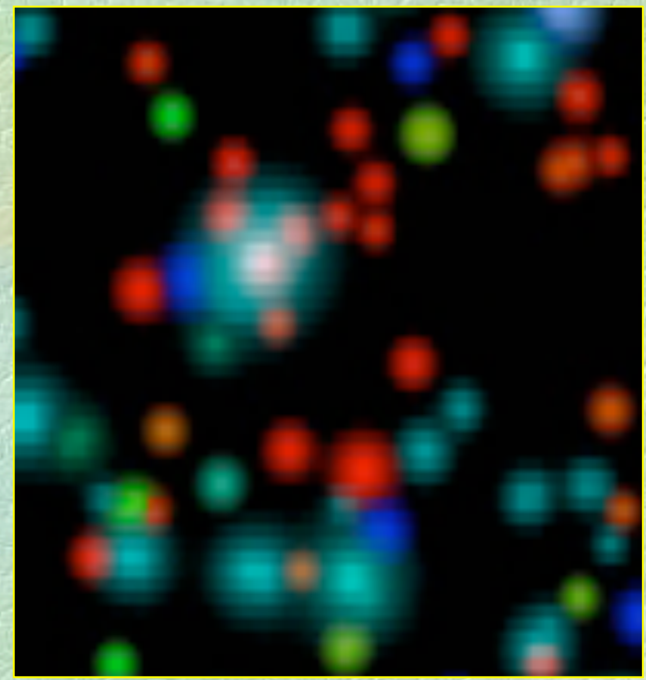
Intensity in log scale

Seeing limited observations in good seeing conditions

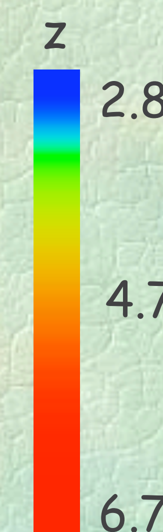
346 gal.arcmin^{-2} in total, 112 gal.arcmin^{-2} in z=[4-6.7]$^{Ly\alpha}$

Source confusion





Intensity in log scale

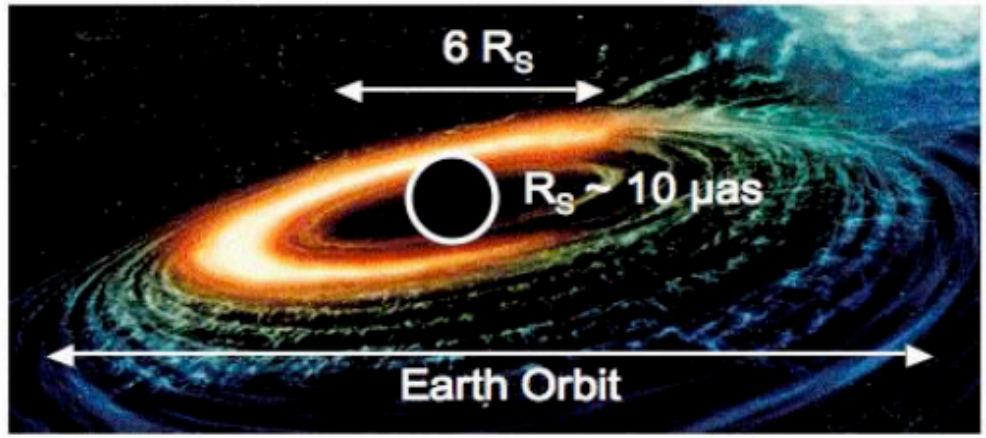


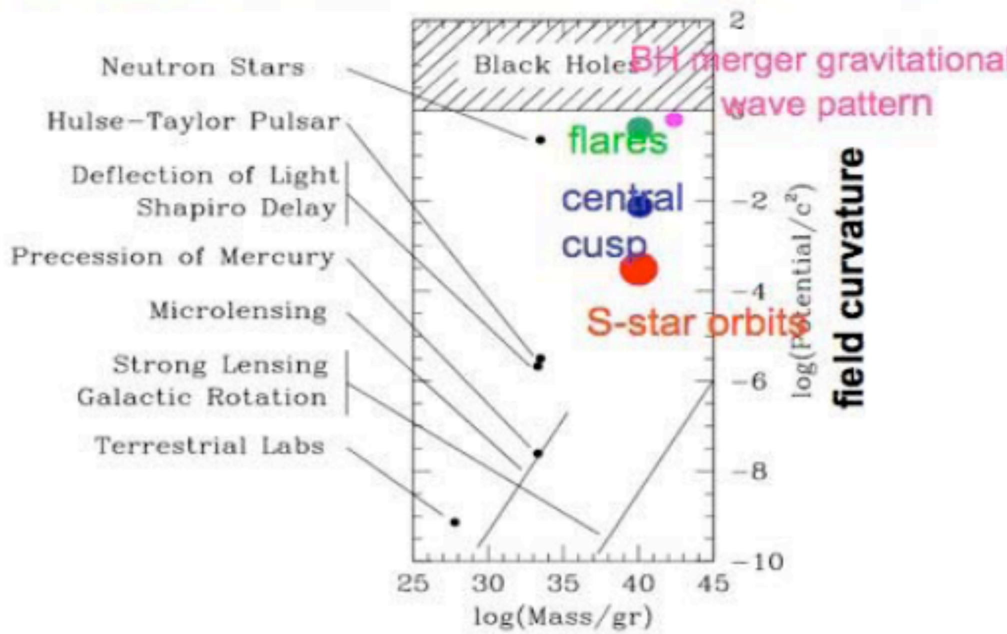
AO observations in good seeing conditions

399 gal.arcmin^{-2} in total, 132 gal.arcmin^{-2} in z=[4-6.7] Lyα

VLTI: GRAVITY

A dual feed, 4-telescope beam combiner which includes IR adaptive optics and fringe tracking. Aimed at the highest possible sensitivity and astrometric accuracy (10 µas) to study the strong gravitational effects around the SMBH at the center of our Galaxy





Courtesy GRAVITY consortium

VLTI: MATISSE

Successor of **MIDI**:
Imaging capability in the entire mid-IR

Successor of **AMBER**:
Extension down to 2.8 μm
+ General use of closure phases

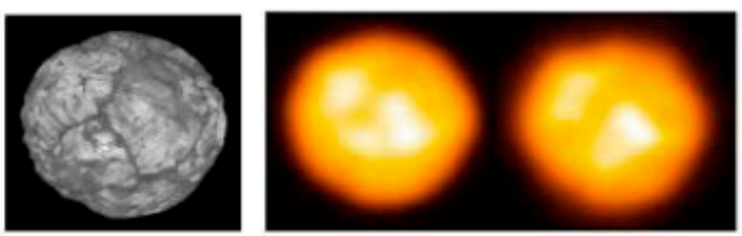
Complement to **ALMA** + **ELT**

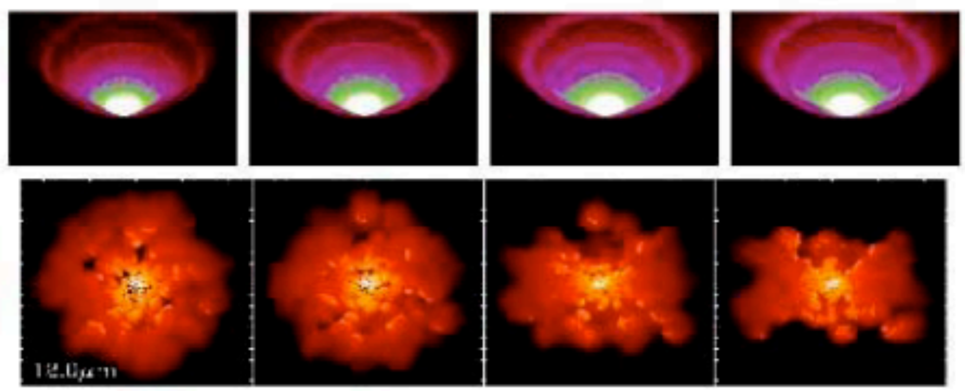
A 4-telescope beam combiner with simultaneous L(M), N bands and moderate spectral resolution. Aimed at thermal imaging of dusty environments of stars and AGNs

PI B. Lopez (Nice),
Partners Nice, Heidelberg, Bonn,

ESO to supply new AQUARIUS detector

Bringing the power of dual-band interferometric imaging to the mid-IR





ESPRESSO

- Outstanding Science

- Competitive, innovative H-R spectrograph to fully exploit the VLT potentiality

- Precursor of CODEX@ELT: Test critical aspects & system performances

Geneve(CH), INAF (Trieste and Brera), IAC (Spain), Porto and Lisboa (Portugal), ESO

ESPRESSO SCIENCE

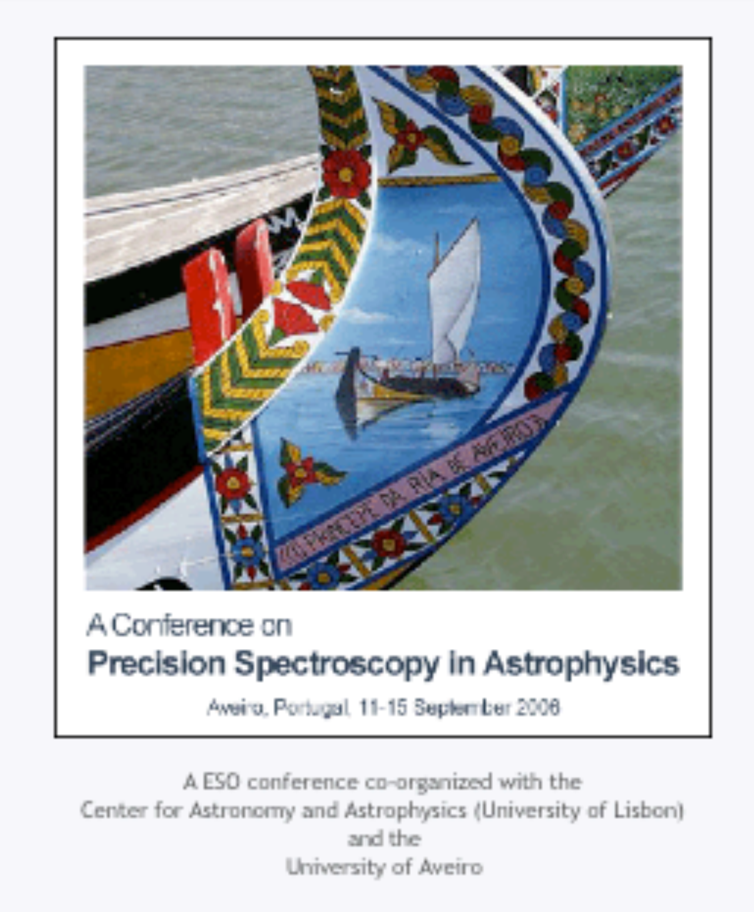
Planet search: Rocky Planets

Variability of Physical Constants

IGM spectroscopy

Abundances in Stars

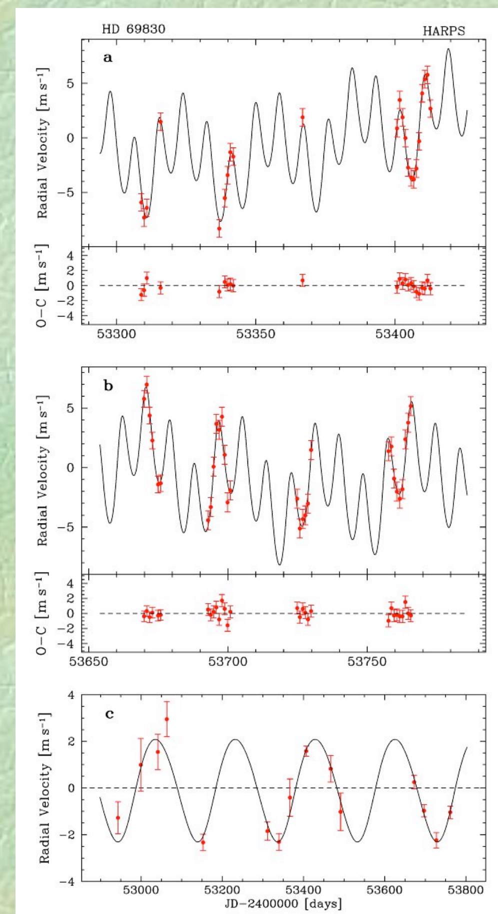
(Additional discussion e.g. in the Proceedings of the Conference On "Precision Spectroscopy in Astrophysics" Santos et al. 2008) c



The HARPS heritage

Vacuum Tank , No moving parts, Mechanical stable
Controlled environment, Simultaneous Calibration
Fibre Fed , Fibre Scrambling

Lovis et al. 2006, 60 cm/sec



ESPRESSO Requirements

Location	Incoherent Coude' room stabilized environment
Telescope diameter	8m and 16m
Feed	Coude' Train + Fibre **(<u>any of the UTs</u>**)
Overall DQE	≥14% at peak (including slit losses for 0.8" seeing)
Wavelength range	370 – 686 nm minimum; Goal: 350 nm to 720 nm or redder
Spectral Resolution	>120 000 (**1 UT, "SuperHARPS"**) >40 000 (**4 UT, "SuperUVES"**)
Doppler Accuracy	10 cm/sec over 30 yrs 1UT, 1m/sec 4UTs
Sampling	>3 pixels/resolution element

Thermally controlled, vacuum, adc, scrambler…

End-to-end operations concept: Operations as automatic as possible, delivery of complete and precise reduced data.

How to improve precision and stability

- **Scramblers to reduce effect of guiding errors**
- **Simultaneous wavelength calibration**
- **Use of wavelength calibration based on "laser comb"**
- **Fully passive instrument, ultra-high controlled temperature stability**
- **Spectrograph in vacuum tank**
- **High precision control of detector temperature**
- **Underground facility, zero human access**
- **Blaze Correction and Flat Fielding**

R&D in Synergy with CODEX

What Beyond ?

1) Upgrades: VIMOS CCD Upgrade: mid-2010
VISIR Detector Upgrade planned
CRIRES Upgrade: study to start

2) CfP for a Survey WIDE FIELD MOS postponed to ~mid-2010 because ELT Inst. Phase A and pending ASTRONET WG recommendation

3) Replacing retired facilities (e.g NAOS) ??

4) ESO is budgeting continued funds for new VLT instrument to 2020 and beyond, though constrained by the reality of financing the E-ELT